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Noise Cancellation in Stochastic Wireless Channels using Coding and Adaptive Filtering

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ABSTRACT
Wireless communication with fading as a major impairment along with other phenomena gives rise to noise in the channel. One of the major issues in wireless communication is to cancel out noise effects primarily when the propagation medium demonstrates stochastic behavior. Data transmission in noisy communication channel is controlled with the help of error control coding. Also, the elimination of noise is effective with the help of adaptive filters as these track the variations in the input signal compared to a given reference signal. In this paper, we explore certain methods of noise cancellation using error correction coding as well as adaptive filter trained with Least Mean Square (LMS), Normalised Least Mean Square (NLMS) and Recursive Least Square (RLS) algorithm. The experiments performed show satisfactory results in severely faded Nakagami-m channels. The work formulates a methodology for developing certain insight into the use of error control coding and adaptive filtering to fight fading in wireless channel.

General Terms
Algorithms

Keywords
Adaptive filters, Nakagami m fading, convolutional code.

1. INTRODUCTION
Transmission of information in real world communication system is mostly affected by noise thus data quality gets degraded. Error control coding is a practical option for improving the data quality. Again, adaptive filters have the ability to change their own parameters automatically and their design requires little or no knowledge of noise and signal characteristics [1]. Real-time adaptive filtering algorithms and error correction coding techniques are essential components of most present-day communications in both wired and wireless forms.

Here**,** we explore certain methods of noise cancellation using error correction coding as well as adaptive filter trained with Least Mean Square (LMS), Normalised Least Mean Square (NLMS) and Recursive Least Square (RLS) algorithm. The experiments performed show satisfactory results in severely faded Nakagami-m channels. The work formulates a methodology for developing certain insight into the use of error control coding and adaptive filtering to fight fading in wireless channel.

2. THEORETICAL BACKGROUND
In this section, we briefly describe the theoretical notions essential for the work.

2.1 Error Control Coding
Error control coding is a technique used for controlling errors in data transmission over noisy communication channel. A predetermined algorithm is used for adding redundancy to the transmitted information and this is how forward error correction is accomplished. Figure 1 below depicts a trellis for a convolutional encoder.

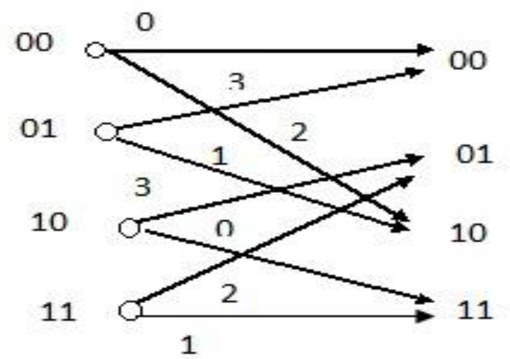

Fig 1: Trellis for a convolutional encoder

2.2 Adaptive Filter
An adaptive filter comprises of two basic components [2], these are a digital filter and an adaptive algorithm. The digital filter produces an output in response to an input signal and the adaptive algorithm is responsible for adjusting the coefficients of the digital filter.

The block of an adaptive filter is shown in Figure 2. The signal d (n) is called the desired signal. The input and the output of the filter are denoted by x (n) and y (n) respectively. The signal e (n) is called the estimation error and is defined by e (n) =d (n)-y (n). The error signal contributes some objective function and the adaptive algorithm aims to minimize those functions.

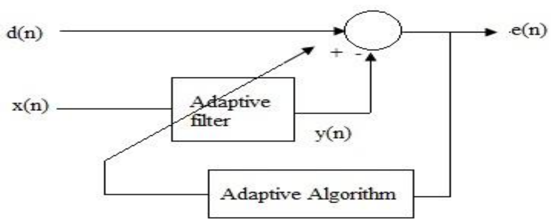

Fig 2: Adaptive Filter Block Diagram

2.3 Adaptive Noise Cancellation

The block diagram of a dual input adaptive noise canceller is shown in Figure 3. The adaptive noise canceller mainly consists of two sensors: primary sensor, which intends to supply a desired signal along with noise and a reference sensor which is responsible for supplying noise alone.

The signal and noise at the output of the primary sensor are uncorrelated and the noise at the output of the reference sensor is correlated with the noise component of the primary-sensor output. The adaptive filter operates on the reference sensor output and thus produces an estimate of the noise and this is subtracted from the primary sensor output [2]. The adjustments applied to the tap weights in the adaptive filter are controlled with the aid of the overall output of the adaptive noise canceller. The adaptive canceller tends to minimize the mean-square error (MSE) value of the overall output, thereby causing the output to be the best estimate of the desired signal in the minimum-mean-square error sense [3].

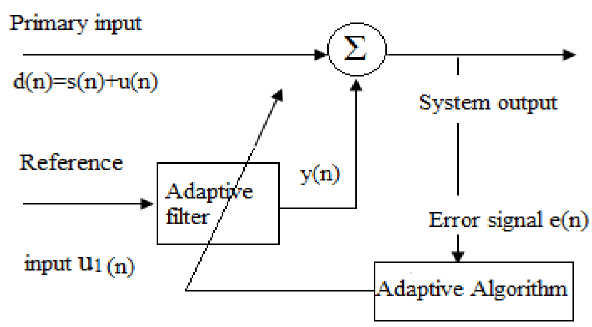

Fig 3: Dual input Adaptive Noise Canceller

There are two criteria on which the design of an adaptive filter depends. It mainly designs itself based on the characteristics of the input signal to the filter and also on a signal that represents the desired behavior of the filter on its input.

2.4 Adaptive Algorithms

Adaptive algorithms can be broadly classified as under:

- Stochastic Gradient Algorithms
- Recursive Least Square Algorithms

The LMS algorithm is a stochastic gradient algorithm; it iterates each tap weight of a transversal filter in the direction of the gradient of the squared magnitude of the error signal with respect the tap weight [2]. The main demerit of the LMS algorithm is that it is sensitive to the scaling of its input. The stability of the LMS algorithm is guaranteed by a learning rate μ, which is not easily chosen due to its sensitivity. This problem can be solved with the help of the Normalized Least Mean Square Algorithm (NLMS), which is a variant of the LMS algorithm, by normalizing with the power of the input. Further, slow convergence and high sensitivity to the Eigen value spread are some of the problems associated with the LMS algorithm which can be solved by using the RLS algorithm. The RLS algorithm represents increased complexity, computational cost and fidelity [4].

2.5 Stochastic Wireless Channels

Wireless communication exhibit a physical phenomenon called fading associated with the transmitted signals [6]. To combat fading many mathematical models are used among which Nakagami fading model is widely adopted. Nakagami fading provides a generalized model for analysis and design and gives a simplistic methodology for conversion between different stochastic behaviors. It is reliable when compared to other fading models like Rayleigh and log-normal. Also, Nakagami-m distribution gave the best fit to some urban multipath data [7].

The Nakagami-m distribution is given by

$$f(x) = \frac{2}{\Gamma(m)} \left(\frac{m}{P}\right)^{m} . x^{2m-1} . exp\left(-\frac{m}{P} x^2\right)$$

Γ (.) is the gamma function, P is the signal power and m is the fading parameter. For m=1, the Nakagami-m distribution reduces to a Rayleigh distribution and for 1<m<2, the Nakagami- m distribution tends to a Rician distribution [8]. The probability density function of Nakagami-m fading channel is given in figure 4.

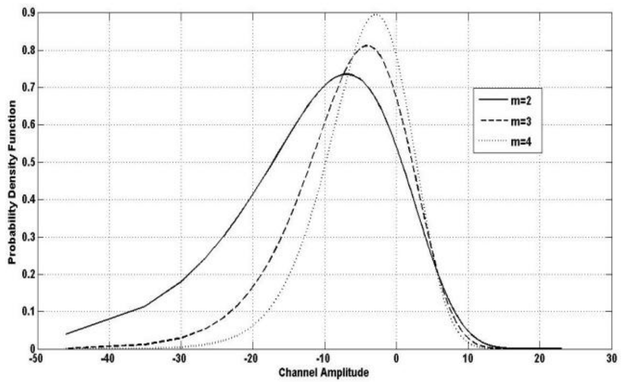

Fig 4: Probability Density Function for Nakagami-m distribution for different m values

3. NOISE CANCELLATION IN STOCHASTIC WIRELESS CHANNELS USING CODING AND ADAPTIVE FILTERING: EXPERIMENTAL CONSIDERATIONS

Here, some noise cancellation experiments are described which have been performed using error correcting convolutional codes and adaptive filter trained with LMS, NLMS and RLS algorithms. Nakagami-m distribution is used to generate the fading channel characteristics. The corresponding BER curves are plotted for all the cases.

3.1 Noise Cancellation using Error Control Coding

Here, convolutional code is used as the technique for error control coding. The performance of a binary communication system that uses binary phase shift keying (BPSK) modulation is shown. Encoding operation in convolutional coding is done by discrete time convolution of the input sequence with the impulse response of the encoder. Modulo-2 convolution is used as the method for generating redundant bits for convolution code. Generation of a binary convolution code is done by passing the information sequence to be transmitted through a linear finite shift register. An (n, 1, K) convolutional code contains K stages of shift registers and n linear modulo-2 function generators [9]. The Viterbi algorithm is used as the decoding method for convolutional code. It is a maximum likelihood decoding algorithm. The path that is most likely to have generated the received signal is found by using the Viterbi algorithm which searches through the trellis diagram upon receiving the channel output. The process diagram for convolutional code is shown in figure 5.

3.2 Adaptive Noise Cancellation in Nakagami fading channel

Adaptive filters trained with LMS, NLMS and RLS algorithm initially track variations in Nakagami-m fading channel and perform noise cancellation. A complex, uncorrelated white Gaussian noise with zero mean and unit variance is generated and added to the channels. The adaptive filter operates on the noise corrupted signal and produces an estimate of the noise, which is subtracted from the desired signal. The overall output is used to control the adjustments applied to the tap weights in the adaptive filter. The flowchart shown in figure 6 depicts the above method.

4. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental process logic is depicted by a flowchart shown in Figure 6. The results were obtained using binary frequency shift keying modulation (BFSK) and minimum shift keying (MSK) modulation. The Nakagami-m fading envelope has a background noise which is additive Gaussian. The SNR vs. BER plot for FSK modulation and MSK modulation without coding for LMS, NLMS and RLS algorithms and also with coding for LMS, NLMS and RLS algorithms are shown in figures 7-8.

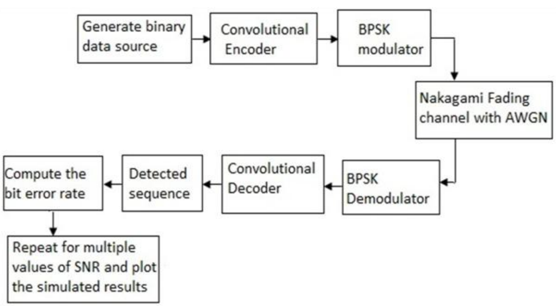

Fig 5: Flowchart depicting convolutional code

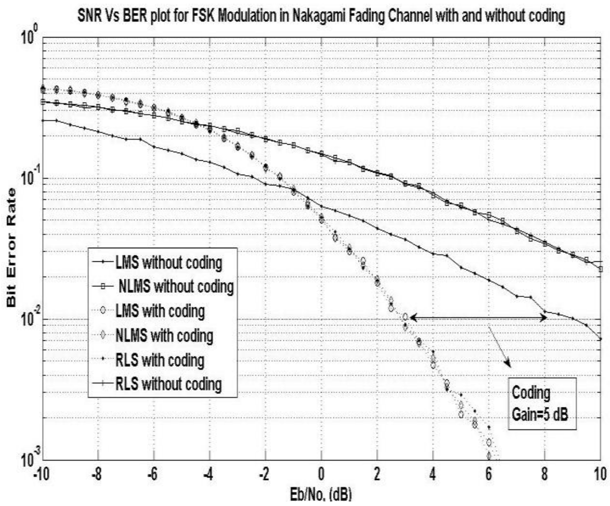

Fig 7: Performance of BFSK modulation using LMS, NLMS and RLS algorithm with and with coding

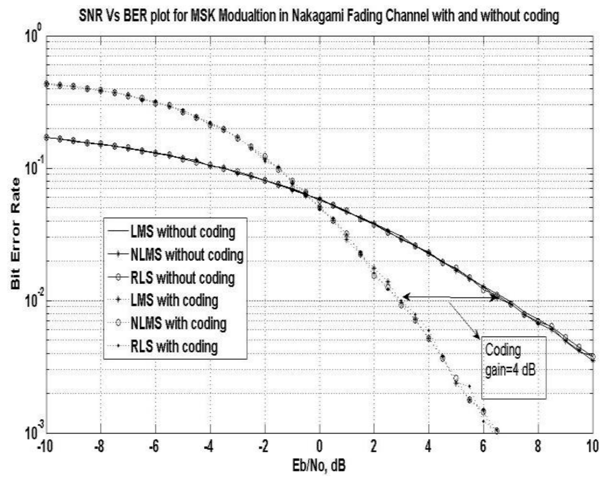

Fig 8: Performance of MSK modulation using LMS, NLMS and RLS algorithm with and with coding.

The estimated waveforms using LMS, NLMS and RLS algorithm with and without coding using BFSK and MSK modulation shown in figure 9 and 10. The coding gain is calculated for FSK and MSK modulation with and without coding and is shown in table 1.

Table 1: Coding Gain for BFSK and MSK

Scheme	BER values	SNR coded	SNR uncoded	Coding Gain(dB)
BFSK	10^{-1}	-1	-2	-1
	10^{-2}	3	8	5
MSK	10^{-1}	-1	-4	-3
	10^{-2}	3	7	4

The result of noise cancellation and the SNR vs. BER plot are plotted for BFSK and MSK modulation using adaptive filter trained LMS, NLMS and RLS algorithm and error control coding and The SNR values vary from -10 to 10 dB.

The framework thus formulated provides satisfactory results while carrying out noise cancellation using adaptive algorithms and convolutional coding. The use of adaptive filtering and error control coding depicts the approach to fight fading in wireless channel. The proposed model gives better results to combat fading compared to the work done in [10].

5. CONCLUSION

Here, we have formulated a framework for noise cancellation using error control coding as well as adaptive filter trained LMS, NLMS and RLS algorithm in severely faded Nakagami-m channel. The experimental results show satisfactory performances and a simplistic arrangement to tackle noise related variations in the channel. With LMS, NLMS and RLS algorithms, MSK provides better performance and on average, provides -3 to 4 dB coding gain in severe faded channels.

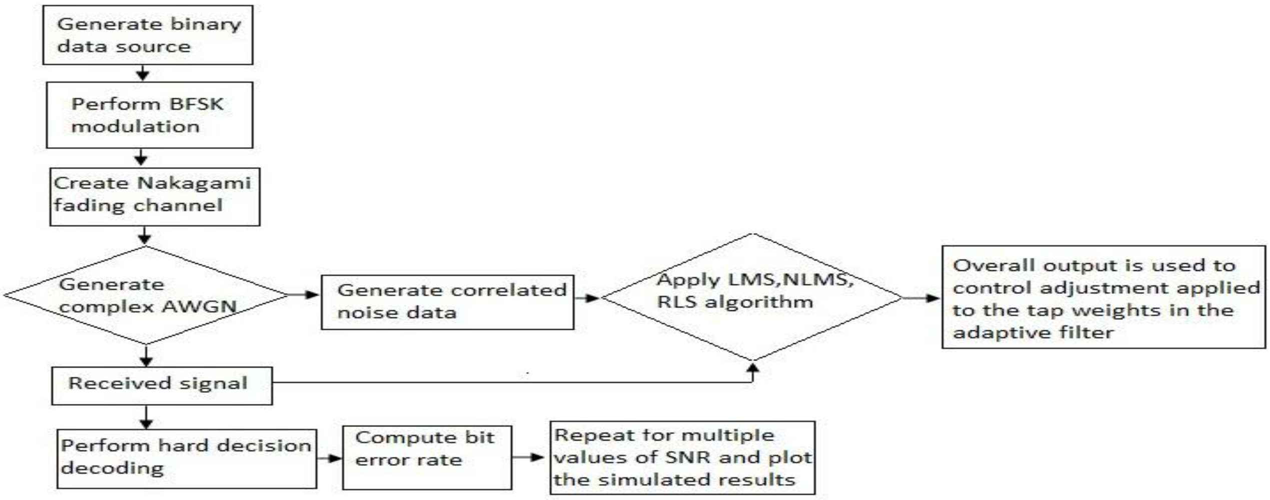

Fig 6: Flowchart depicting the process logic using adaptive filters

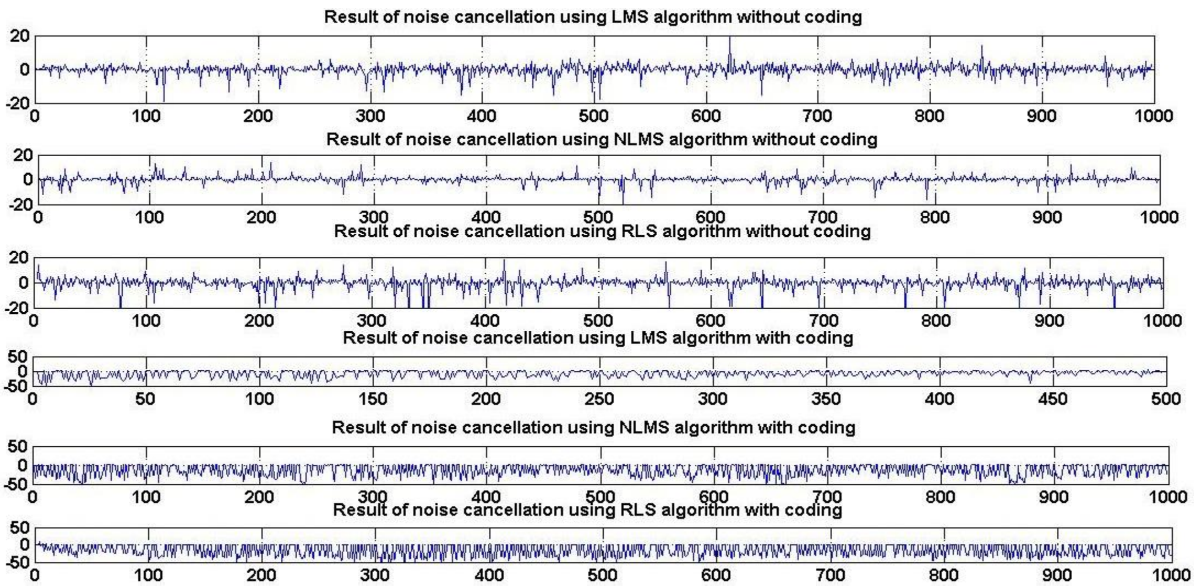

Fig 9: Noise Cancellation for BFSK modulation using LMS, NLMS and RLS algorithm with and with coding.

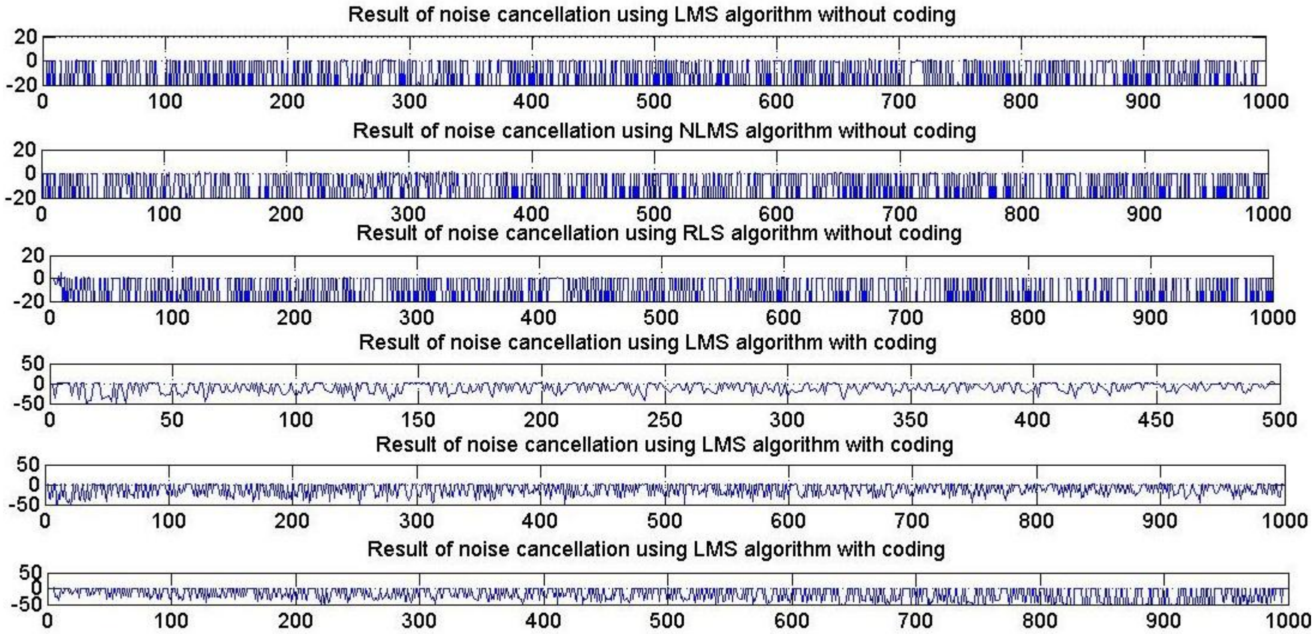

Fig 10: Noise Cancellation for MSK modulation using LMS, NLMS and RLS algorithm with and with coding.

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